

**PATENT APPLICATION**

**Title:**       **AUTOMATED, COMPUTER-BASED READING TUTORING SYSTEMS  
AND METHODS**

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## **BACKGROUND OF THE INVENTION**

### **Field of the Invention:**

The present invention relates generally to literacy tutoring and, more specifically, to automated, computer-based reading tutoring systems and methods particularly adapted to provide literacy tutoring in conjunction with user-specific content learning.

### **Brief Description of the Related Art:**

The demand for alternatives to traditional classroom instruction has been steadily growing, with increasing numbers of individuals being interested in self-guided learning experiences for personal fulfillment and/or career development. Concomitantly, many institutions are recognizing the need to implement educational and training opportunities to retain motivated employees and to remain competitive. Various institutions, for example, are being called upon to provide options for independent study using distance learning technologies. Presently available computer-based education or training, while responding to the aforementioned demands, has presented numerous drawbacks. Many computer-based training systems and methods (CBT) have proven to be too simplistic and “lock-step” to be of much value beyond the acquisition of rudimentary skills or information. Intelligent tutoring systems and methods (ITS) have proven valuable in some highly constrained domains, but generally require levels of effort and expense that are impractical for most applications.

In the area of literacy, there is a great need for self-guided reading tutoring systems and methods to improve the reading skills of learners of various ages. Many learners, particularly adults, are more comfortable and motivated to learn when in a private setting without the fear of public scrutiny and embarrassment. Self-guided reading tutoring systems and methods allow students to learn in comfort and privacy as well as to set their own time and pace for learning, which might otherwise not be possible in a traditional classroom setting.

1 Non-automated reading tutorials utilizing a hierarchical series of reading passages  
2 arranged according to levels of difficulty have been proposed. The passages typically derive from  
3 multiple sources and relate to a single topic. A student is assigned the least difficult passage to  
4 read, and an instructor thereafter manually evaluates the student's understanding of the passage.  
5 Where adequate comprehension is demonstrated, the student advances to the next level of  
6 difficulty, and the instructor must repeat the process of manually evaluating the student's reading  
7 comprehension at each level and selecting the next reading passage. Where the student fails to  
8 pass a particular level, the procedure is repeated for as many passages as needed at the same level  
9 until the student passes. Since reading tutoring systems and methods of the aforementioned type  
10 are very labor intensive, standardized generic instructional materials are developed and used with  
11 all students regardless of a student's interests, work experience, work requirements, prior  
12 knowledge of the subject matter, and individual learning differences. Unless a student happens  
13 to be interested in the subject matter, has frequent and timely interactions with an instructor, and  
14 is able to progress quickly and easily through the levels of difficulty, whatever motivation the  
15 student initially brings to the task is soon dissipated. Furthermore, traditional reading tutorials  
16 of this type are usually lacking in specific features by which vocabulary and reading fluency skills  
17 can be effectively enhanced.

18 An example of a self-paced, "CBT-like" educational package including a reading tutorial  
19 is the PLATO ® educational package developed by TRO Learning, Inc. The PLATO ® reading  
20 series is less labor intensive than traditional manual reading tutorials, but does not incorporate  
21 artificial intelligence to provide customized, learner-specific guidance and motivation. As with  
22 traditional manual reading tutorials, the PLATO ® reading series is pre-packaged with generic  
23 content.

24 There is significant agreement among educators and researchers that a student's ability

1 to produce a good summary of lesson text is superior to other forms of assessment in evaluating  
2 the student's reading comprehension and that learning to write good summaries of lesson text is  
3 an effective way to develop reading comprehension strategies and skills. A major drawback to  
4 using student summaries for instruction and assessment of reading comprehension, however, is  
5 the time and effort required for human experts to evaluate the summaries and provide timely  
6 feedback to the student. Since written summaries must be scored by a human instructor, a  
7 significant delay in time ensues before the results of the scoring can be used to enable instruction  
8 to proceed. Accordingly, it is more typical for reading comprehension to be assessed using  
9 objective questions that can be scored automatically, but which are less valid in measuring actual  
10 comprehension.

11 A major impediment to providing automated, computer-based reading tutoring systems  
12 and methods is the difficulty involved in automating the critical functions of an expert human tutor  
13 to achieve an "ITS-like" learning experience with a "CBT-like" expenditure of effort and expense.  
14 In particular, the inability to automate the analysis and structuring of textual instructional material  
15 within a very large domain of discourse, the evaluation of a student's current reading level, the  
16 determination of the student's understanding of the instructional material, and the generation of  
17 recommendations about the next level of reading difficulty appropriate for the student are great  
18 deterrents to the implementation of automated, computer-based reading tutorials. While latent  
19 semantic analysis (LSA), a fully automatic mathematical/statistical technique for extracting and  
20 inferring relations of expected contextual usage of words in passages of discourse, has been found  
21 capable of simulating a variety of human cognitive phenomena, its applicability to automated,  
22 computer-based reading tutoring systems and methods has thus far not been recognized. U.S.  
23 Patents No. 5,987,446 to Corey et al., No. 5,839,106 to Bellegarda, No. 5,301,019 to Landauer  
24 et al., and No. 4,839,853 to Deerwester et al. are representative of prior applications for latent

1 semantic techniques.

2 Reading accuracy and fluency are known to play an important role in developing reading  
3 comprehension. Oral reading fluency is important because, without developing sufficient speed  
4 to maintain important sentence structures in short term memory, comprehension fails due to  
5 insufficiency of memory resources. Therefore, developing sufficient speed and fluency in reading  
6 are critical to improving reading comprehension. While speed in reading is greatly improved by  
7 repetition and practice, most learners are likely to avoid practice opportunities that might arise  
8 in traditional classroom settings due to the fear of failure. One-on-one fluency tutoring can be  
9 conducted with less fear of embarrassment, but is cost-prohibitive and impractical for most  
10 learners. Traditional reading tutorials, which typically are lacking in fluency instruction, thusly  
11 fail to address the needs of learners for whom the speed and accuracy with which they read are  
12 obstacles to improved reading comprehension. In particular, it is not possible with traditional  
13 reading tutorials to practice oral reading fluency in an automated environment using speech  
14 recognition software.

## 15 SUMMARY OF THE INVENTION

16 Accordingly, it is a primary object of the present invention to overcome the  
17 aforementioned disadvantages of prior reading tutoring systems and methods.

18 Another object of the present invention is to incorporate artificial intelligence in a reading  
19 tutorial to provide learner-specific guidance and motivation.

20 A further object of the present invention is to utilize user-specific instructional material  
21 in automated, computer-based reading tutoring systems and methods.

22 An additional object of the present invention is to automate the analysis of student-  
23 produced summaries of lesson text in reading tutoring systems and methods as a measure of  
24 reading comprehension.

1 It is also an object of the present invention to automatically guide a student to the  
2 appropriate level of reading difficulty in a large body of lesson text of a reading tutorial, so as to  
3 develop a path of optimal learnability through the lesson text.

4 Yet another object of the present invention is to utilize machine learning algorithms to  
5 automate computer-based reading tutoring systems and methods.

6 The present invention has as a further object to incorporate voice recognition in  
7 automated, computer-based reading tutoring systems and methods.

8 A still further object of the present invention is to incorporate automated summary,  
9 vocabulary and/or fluency tutors in computer-based reading tutoring systems and methods.

10 Additionally, it is an object of the present invention to provide immediate feedback  
11 regarding the quality of a summary submitted by a student to assess reading comprehension in  
12 computer-based reading tutoring systems and methods.

13 Some of the advantages of the present invention are that the computer-based reading  
14 tutoring systems and methods are designed so students spend most of the instructional time  
15 engaged in reading; the summaries used to assess a student's reading comprehension may be  
16 submitted audibly so that assessing reading comprehension skill is not confounded with writing  
17 skill; a student's understanding of the subject matter of the lesson text before and after reading  
18 each passage or lesson is used to effectively identify the most appropriate passage or lesson to be  
19 attempted next; a student is assisted in developing comprehension of the lesson text as well as  
20 strategies to improve comprehension skills in general; the computer-based reading tutoring  
21 systems and methods are more effective, less costly to develop and administer, and are more  
22 engaging for the student than traditional reading tutorials; the computer-based reading tutoring  
23 systems and methods are particularly adaptable to adult learners but may be designed for various  
24 age groups and reading levels; the student's motivation and interest are maintained via immediate

1 feedback, interactive exercises and the realization of a successful experience based on user-  
2 specific selection of lesson text; the computer-based reading tutoring systems and methods may  
3 incorporate safeguards against suspect summaries; the computer-based reading tutoring systems  
4 and methods may contain a broad variety of content areas selected for individual students, or self-  
5 selected, based on various individually-suited purposes; the need for human instructors is  
6 eliminated; students with a history of unsuccessful reading and testing will feel more comfortable  
7 and less intimidated; and new instructional materials may be introduced into the automated,  
8 computer-based reading tutoring systems and methods with minimal authoring effort.

9         These and other objects, advantages and benefits are realized with the present invention  
10 as generally characterized in a reading tutoring system including at least one domain of discourse  
11 accessible by a student via a computer system and comprising a plurality of instructional passages  
12 of different, predetermined levels of reading difficulty for the student to read via a monitor of the  
13 computer system. One or more semantic space modules of the reading tutoring system receives  
14 a summary of a selected instructional passage prepared by the student and submitted via the  
15 computer system either audibly or in writing. The one or more semantic space modules uses  
16 semantic spaces produced by latent semantic analysis (LSA) or other machine learning methods  
17 to automatically evaluate the summary for congruence of content with the selected instructional  
18 passage and, based on the degree of congruence, to automatically determine which instructional  
19 passage from the domain of discourse the student should read next. The reading tutoring system  
20 includes immediate feedback data provided to the student via the computer system, the immediate  
21 feedback data comprising an indicator reflective of the degree of congruence between the  
22 summary and the selected instructional passage, and comprising the identity of the instructional  
23 passage that the student should read next. The reading tutoring system may also include a  
24 comprehension tutor module, a vocabulary tutor module and/or a fluency tutor module selectively

1 accessible by the student or assigned to the student via the computer system. The comprehension  
2 tutor module communicates key words from the selected instructional passage via the computer  
3 system and presents the student with interactive summarizing instruction and exercises including  
4 the option of submitting a practice summary of the selected instructional passage. Where a  
5 practice summary is submitted, the one or more machine learning modules of the reading tutoring  
6 system evaluates the practice summary for congruence of content with the selected instructional  
7 passage. The immediate feedback data includes information regarding the student's responses to  
8 the interactive practice exercises and the quality of the practice summary where a practice  
9 summary is submitted. The vocabulary tutor module communicates principal vocabulary words  
10 via the computer system, including the communication of definitions, synonyms, antonyms,  
11 samples of correct usage and interactive practice exercises for the principal vocabulary words.  
12 Where the interactive practice exercises are utilized, the vocabulary tutor module evaluates the  
13 student's responses to the interactive practice exercises, and the immediate feedback data  
14 includes information regarding the student's performance on the interactive practice exercises.  
15 The fluency tutor module is implemented using a voice recognition system of the reading tutoring  
16 system and audibly communicates an audibly correct reading of the instructional passage for the  
17 student to listen to. The fluency tutor module receives an audible reading of the selected  
18 instructional passage by the student and automatically evaluates the student's reading for accuracy  
19 and speed. Where the fluency tutor module is utilized, the immediate feedback data includes  
20 information regarding the accuracy and speed of the student's reading.

21 The present invention is further characterized in an automated, computer-based method  
22 of reading tutoring comprising the steps of providing a domain of discourse accessible by a  
23 student via a computer system and including a plurality of instructional passages of different,  
24 predetermined levels of reading difficulty, selecting an instructional passage for the student to read

1 on a monitor of the computer system, receiving a summary of the selected instructional passage  
2 prepared by the student and submitted via the computer system, automatically evaluating the  
3 summary for congruence with the selected instructional passage to obtain a measure of the  
4 student's reading comprehension, automatically selecting an instructional passage from the  
5 domain that the student should read next based on the congruence of the summary with the other  
6 instructional passages, communicating feedback data to the student via the computer system  
7 including an indicator reflective of the student's reading comprehension and including the identity  
8 of the instructional passage to read next, and repeating the receiving, the automatically evaluating,  
9 the automatically selecting and the communicating steps for the instructional passage that the  
10 student reads next.

11 The present invention is also characterized in an automated, computer-based method of  
12 self-guided reading tutoring comprising the steps of accessing a domain of discourse of a reading  
13 tutoring system via a computer system, reading an assigned instructional passage from the domain  
14 of discourse via a monitor of the computer system, preparing a summary of the assigned  
15 instructional passage, submitting the summary to the reading tutoring system via the computer  
16 system, receiving immediate feedback data from the reading tutoring system including an indicator  
17 reflective of the congruence of the summary with the assigned instructional passage and  
18 including the identity of a recommended instructional passage from the domain that should be read  
19 next based on the congruence of the summary with the assigned instructional passage, and  
20 repeating the steps of reading, preparing, submitting and receiving for the recommended  
21 instructional passage.

22 These and other objects, advantages and benefits of the present invention will become  
23 apparent upon consideration of the following detailed description of preferred embodiments  
24 thereof, particularly when taken in conjunction with the accompanying drawings, wherein like

reference numerals in the various figures are utilized to designate like or similar components.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

Fig. 1 illustrates, partly in block diagram, a computer system for implementing the reading tutoring systems and methods according to the present invention.

Fig. 2 illustrates in block diagram a reading tutoring system according to the present invention.

Fig. 3 is a block diagram illustrating a domain of discourse for the reading tutoring system of Fig. 2.

Fig. 4 is a flow diagram illustrating a method of reading tutoring according to the present invention.

Fig. 5 is a flow diagram illustrating an alternative method of reading tutoring according to the present invention incorporating the use of a comprehension tutor.

Fig. 6 is a flow diagram illustrating an alternative method of reading tutoring according to the present invention incorporating the use of a vocabulary tutor.

Fig. 7 is a flow diagram illustrating an alternative method of reading tutoring according to the present invention incorporating the use of a fluency tutor.

## **DESCRIPTION OF THE PREFERRED EMBODIMENTS**

The reading tutoring systems and methods according to the present invention are implemented using a conventional computer system, such as computer system 10 illustrated in Fig.

1. Computer system 10 typically includes a monitor 12 for visually displaying information to a user, a central processing unit 14, internal memory 16, a keyboard 18 for inputting information to central processing unit 14, and a mouse 20 for selecting icons displayed on monitor 12. A disk drive 22 and modem 24 of computer system 10 provide alternate avenues for data input to the central processing unit 14. Computer system 10 may include a voice recognition system 25 with

1 a microphone input 27 for voice input. Computer system 10 communicates with a user graphically  
2 via monitor 12, as well as audibly. A printer 26 of computer system 10 allows output data to be  
3 embodied in tangible print form. The reading tutoring systems and methods of the present  
4 invention can be embodied in a stand-alone program for computer system 10 and/or an  
5 internet/intranet network database application accessible via computer system 10 as represented  
6 by network 23. Implementation as a WWW-based application allows use of a single URL for  
7 accessing the reading tutoring system. Preferably, the reading tutoring systems and methods of  
8 the present invention will operate under the Windows 95/98/NT operating system, as a stand-  
9 alone program, and as a client-server WWW-based network application. The internet version of  
10 the reading tutoring systems will typically have a client/server split with all GUI/interactive  
11 tutoring on the client side and all command/assessment functions on the server side.

12 A reading tutoring system 28 according to the present invention is illustrated in block  
13 diagram in Fig. 2 and includes a graphical user interface (GUI) 29 by which a student, i.e. a user  
14 of the reading tutoring system, interacts with the reading tutoring system, a command unit 30  
15 comprising software for executing the various diverse functions performed by the reading  
16 tutoring system, at least one domain of discourse 31 accessible via the computer system 10 for  
17 display on monitor 12, a validity check module 33, at least one semantic space module (SS  
18 module) 34, and feedback data or information 36. The graphical user interface (GUI) 29 is a  
19 user-friendly interface by which the reading tutoring system communicates visually or graphically  
20 or audibly with a student and by which the student interacts with the reading tutoring system via  
21 the computer system 10. Graphical user interface 29 includes a "student login" by which the  
22 student is prompted, typically via monitor 12, to enter an identifier such as an "ID" and  
23 "password". The reading tutoring system 28 stores information associated with a student's "ID"  
24 and "password" including history of use for the student, which may be displayed on monitor 12.

1 The graphical user interface 29 includes a display option allowing the student to begin with a new  
2 lesson or to continue a lesson previously begun. The graphical user interface 29 further includes  
3 multi-media introduction and help information, which may depict a person or persons with whom  
4 the student will make a positive identification. A “quit” option of the graphical user interface 29  
5 is always available, with the ability for the student to re-start at the same point. Preferably, the  
6 graphical user interface 29 includes instruction and cues in graphical or textual and/or audio form.  
7 The graphical user interface may also provide means for students to select speech tasks and to  
8 control the recording of orally read summaries as discussed further below.

9 The command unit 30 includes a body of software controlling operation of the reading  
10 tutoring system and managing the student’s interaction therewith. The command unit 30 controls  
11 the exchange of visual and audible information with the student in response to selections and input  
12 entered by the student.

13 Domain of discourse 31 is a database comprising a large corpus of text relating to a topic  
14 or subject that is relevant to a student, based on personal interest, job or career relatedness, need  
15 for information and/or other individually-suited purposes. The domain of discourse 31 includes  
16 a plurality of passages or lessons 32 arranged hierarchically according to their levels of reading  
17 difficulty or content and used as instructional passages in the reading tutoring system. The  
18 semantic space module 34 receives a summary of an assigned passage 32 read by the student  
19 from the domain of discourse 31, the assigned passage being displayed on monitor 12. The  
20 summary can be submitted in writing, via the keyboard 18, or orally via the voice recognition  
21 system 25 of the reading tutoring system. After the validity check module 33 “checks” or  
22 evaluates the student-submitted summary for plagiarism and/or other anomalies, the semantic  
23 space module 34 automatically evaluates or “scores” the student-submitted summary to assess  
24 the student’s comprehension of the assigned passage. Based on this evaluation, the reading

tutoring system determines the passage of appropriate reading difficulty that the student should read next. Feedback data or information 36 is provided to the student immediately via computer system 10 in accordance with the evaluation performed by the one or more machine learning modules.

The reading tutoring system 28 includes at least one domain of discourse 31 but may include one or more additional domains of discourse, such as domains of discourse 31' and 31" shown in Fig. 2. The domains of discourse 31' and 31" are accessible via the computer system 10 and may relate to the same topic or subject as domain of discourse 31, or may relate to topics or subjects different from the topic or subject of domain of discourse 31 so as to provide the student with a broad variety of content areas from which the domain of discourse most relevant to the student can be selected. As with the domain of discourse 31, the domains of discourse 31' and 31" each include a plurality of passages arranged hierarchically according to their levels of reading difficulty or content. The semantic space module 34 or a different semantic space module of the reading tutoring system automatically evaluates a student-submitted summary of an assigned passage from the domains of discourse 31' or 31" in the manner discussed above and, based on this evaluation, the reading tutoring system 28 determines the next passage of appropriate difficulty that the student should read next.

The reading tutoring system 28 includes at least one semantic space module 34, but may include one or more additional semantic space modules, such as semantic space modules 34' and 34" shown in Fig. 2, for performing different analytical functions of the reading tutoring system. The semantic space modules each comprises a body of software for executing a semantic space method or procedure by which textual input, i.e. a student-submitted summary, is accepted and is related to data produced by a machine-learning method or procedure, such as latent semantic analysis (LSA), HAL, EM (Expected Means) or other machine-learning methods. The semantic

1 space modules may incorporate semantic space algorithms for accepting the textual input and  
2 relating its component words to the data produced by the machine-learning method, which may  
3 be executed using a machine-learning algorithm. The present invention can be implemented using  
4 semantic spaces produced by any suitable machine-learning method, and the reference herein to  
5 latent semantic analysis (LSA) is for exemplary purposes to simplify description of the present  
6 invention. Accordingly, as described herein by way of example, the machine-learning method  
7 incorporates data derived from latent semantic analysis (LSA), a fully automatic  
8 mathematical/statistical technique for extracting and inferring relations of expected contextual  
9 usage of words in passages of discourse. LSA is a method for determining and representing the  
10 similarity of meaning of words and passages. After processing a large sample of text, LSA  
11 represents the words used in it, and any set of these words – such as those contained in a  
12 sentence, paragraph, or essay, either taken from the original text or another source – as points in  
13 a very high dimensional (e.g., 50 - 1000) content vector space or “semantic space.” LSA may be  
14 viewed as a special kind of machine learning algorithm that learns associative relations between  
15 individual words and the meaning-bearing contexts in which they occur. However, LSA utilizes  
16 an efficient machine learning method called singular value decomposition (SVD). SVD is a  
17 mathematical matrix decomposition technique which allows training on amounts of natural text  
18 comparable to those from which humans acquire domain knowledge. The basis of SVD, as used  
19 in LSA, is a high-dimensional linear decomposition of a matrix containing data on the frequency  
20 of use of thousands of individual words in thousands of sentences or paragraphs. A dimension  
21 reduction step constitutes a form of induction by multiple constraint satisfaction that empirically  
22 simulates human judgment of meaning from text to a remarkable degree. U.S. Patents No.  
23 5,987,446 to Corey et al, No. 5,839,106 to Bellegarda No. 5,301,019 to Landauer et al., and No.  
24 4,839,853 to Deerwester et al., the disclosures of which are incorporated herein by reference, are

1 representative of latent semantic techniques. An EM method is discussed by A.P. Dempster,  
2 N.M. Laird and D.B. Rubin in "Maximum Likelihood From Incomplete Data Via the EM  
3 Algorithm", Journal of the Royal Statistical Society, Series B (1977), the disclosure of which is  
4 incorporated herein by reference. A HAL method is discussed by K. Lund and C. Burgess in  
5 "Producing High-Dimensional Semantic Spaces From Lexical Co-occurrence", Behavior Research  
6 Methods, Instrumentation, and Computers (1996), the disclosure of which is incorporated herein  
7 by reference. In the present invention, LSA represents words statistically as data in a high-  
8 dimensional vector space to produce one or more semantic spaces, and the semantic space  
9 algorithm operates directly on this data or one or more semantic spaces. The results of these  
10 operations are used to infer information about the qualities of the textual input and to make  
11 decisions based on the inferences. Examples of semantic space methods include evaluating  
12 student summaries by reference to the text of the original passage, selecting principle words from  
13 the original passage, selecting the next passage for a particular usage, and evaluating the similarity  
14 of two passages.

15 Semantic spaces derived from LSA or other machine-learning methods are used in the  
16 reading tutoring systems and methods of the present invention to automatically compare a passage  
17 from a domain of discourse with a student-submitted summary of the passage to produce a  
18 numerical similarity score indicative of the conceptual or content similarity or congruence between  
19 the passage and the student-submitted summary. Higher similarity scores reflect greater  
20 congruence between the student's existing semantic structure or schema and that represented by  
21 the passage. Hence, higher similarity scores reflect greater comprehension or understanding by  
22 the student of the content or subject matter of the passage. Also, semantic spaces are used in the  
23 reading tutoring systems and methods of the present invention to automatically select and order  
24 the passages that the student should read from the domain of discourse to establish a customized

1 path of optimal learnability for the student through the domain of discourse based on the  
2 congruence or semantic relatedness between the passage most recently read by the student and  
3 the student-submitted summary corresponding thereto, as well as the congruence or semantic  
4 relatedness between the student-submitted summary and the other passages in the domain. The  
5 path of optimal learnability for the student will be one that begins with high, but not total,  
6 congruence and gradually moves the student toward greater congruence with larger portions of  
7 the domain of discourse.

8 The voice recognition system 25, which converts oral input or dictation to text, allows  
9 a student to submit audible or oral input to the reading tutoring system, in that the audible input  
10 is converted to text for processing by the reading tutoring system. The voice recognition system  
11 25 allows a student to submit an oral or dictated summary of a passage 32 for evaluation by the  
12 one or more semantic space modules 34, 34' or 34". Regardless of whether it is spoken or typed  
13 by the student, the summary is analyzed the same way, although different scores may be used as  
14 thresholds. The reading tutoring system 28 is particularly advantageous where a student's current  
15 writing skills are poor and/or the improvement of writing skills are not of major concern. In many  
16 instances, the acquisition of knowledge of the subject matter of the domain of discourse and/or  
17 the ability to perform a non-writing task are often of primary importance. Writing a summary  
18 would, for many students, be a confounding factor in the assessment of reading comprehension.  
19 The ability of the reading tutoring system 28 to accept summaries as either speech or written input  
20 greatly increases its applicability, especially to individuals with disabilities who may not be able  
21 to use a keyboard, its ease of use and its effectiveness. The voice recognition system 25 also  
22 assists in implementing the fluency tutor module discussed below. The voice recognition system  
23 25 may incorporate commercial speech recognition technology, such as that represented by the  
24 speech recognition software systems know as "NaturallySpeaking" of Dragon Systems, and "Via

1 Voice” of IBM.

2 The validity check module 33 includes a body of software for preprocessing a student-  
3 submitted summary to check for plagiarism or other anomalies, allowing a suspect summary to  
4 be “flagged” for evaluation by a human instructor. The validity check module can operate in  
5 various ways to identify suspect summaries in response to one or more detected parameters, such  
6 as word usage, word count, i.e, where the summary is too short or too long to be a valid  
7 summary, and/or other parameters or peculiarities.

8 The reading tutoring system 28 provides immediate feedback data 36 to the student, via  
9 the computer system 10, regarding the similarity between the student-submitted summary and the  
10 corresponding instructional passage, and regarding the passage of the domain of discourse which  
11 the student should attempt to read next. The feedback data 36 is based on the student’s similarity  
12 score and/or some other metric, measurement or indicator reflective of the congruence of the  
13 student-submitted summary with the corresponding instructional passage, as determined by the  
14 one or more machine learning modules. For example, feedback data 36 may include “pass” or  
15 “try again” designations selectively assigned by the reading tutoring system to the student’s most  
16 recently submitted summary in accordance with the evaluation performed by the one or more  
17 machine learning modules. The feedback data 36 may include specific recommendations for  
18 improving components of the summary. The feedback data 36 also includes a recommendation  
19 or instruction identifying to the student which passage from the domain of discourse the student  
20 should read next.

21 In this manner, the student is guided through the domain of discourse in accordance with  
22 the student’s existing, prior and developing knowledge, as reflected in the semantic relatedness  
23 of the student’s summary with the content of the assigned instructional passage. The student may  
24 be directed by the reading tutoring system to a particular recommended passage or to select one

of several recommended passages to read next. Where the student's most recently submitted summary has obtained a relatively high "pass" score, the one or more passages which the student is directed by the reading tutoring system to read next will typically be of a higher level of reading difficulty than the passage corresponding to the most recently submitted summary. Where the student's most recently submitted summary has obtained a relatively low "pass" score, the one or more passages which the student is directed by the reading tutoring system to read next will typically be at or about the same level of reading difficulty as the passage for which the most recent summary was submitted. Where the student's most recently submitted summary has obtained a "try again" designation, the student is typically directed by the tutoring system to reread the same passage for which the most recent summary was submitted, to read one or more other passages at the same level of difficulty as the passage for which the most recent summary was submitted, or to read one or more passages of a lower level of reading difficulty than the passage for which the most recent summary was submitted. Where the student's most recently submitted summary receives a "try again" designation, feedback data 36 may also include a direction for the student to utilize aspects of a comprehension tutor or other tutors of the reading tutoring system as explained further below. Of course, feedback data 36 may include various additional metrics useful to the student and obtained via the evaluation performed by the one or more semantic space modules, such as an indication of words not understood by the student in the most recently read passage and/or components missing from the student-submitted summary as compared to the original passage. Feedback data 36 also includes feedback information provided in conjunction with comprehension, vocabulary and/or fluency tutors of the reading tutoring system as described further below. The feedback data 36 may be visually displayed on monitor 12, may be delivered audibly and/or may be obtained via printer 26 in tangible print form.

The reading tutoring system 28 preferably includes one or more automated tutors for

1 focused skill development in specific areas such as comprehension or summarizing, vocabulary  
2 and/or fluency. Three tutor modules, i.e. a comprehension or summary tutor module 38, a  
3 vocabulary tutor module 40 and a fluency tutor module 42, are provided in reading tutoring  
4 system 28. The central feature of the comprehension tutor module 38 is direction and practice  
5 in constructing a good summary. The comprehension tutor module is a distinct subsystem of the  
6 reading tutoring system 28 and comprises a body of software supporting instruction, practice and  
7 feedback in some component information processing skills that contribute to reading  
8 comprehension. The comprehension tutor module 38 provides information to the student, via  
9 computer system 10, relating to summarizing skills as a strategy and product of reading  
10 comprehension and provides embedded tutoring features. Key words, i.e. words that carry special  
11 significance with respect to the content and meaning of the passage, may be presented as  
12 highlighted terms within the passage. The comprehension tutor module 38 provides interactive  
13 summarizing instruction and exercises or activities for the student using passages from the domain  
14 of discourse. The comprehension tutor module 38 provides interactive activities designed to  
15 improve comprehension skills and may include “drag and drop” activities such as the following:  
16 a sequencing activity where the student arranges sentences from the lesson passage into their  
17 correct order; a “cloze” activity where a student “drags” appropriate words from a word bank into  
18 blank spaces within the lesson passage; and an activity where the student identifies the core  
19 concept of a lesson passage and its related ideas. The comprehension tutor module  
20 automatically evaluates the student’s performance on the various summarizing activities and  
21 provides immediate feedback to the student, as feedback data 36, regarding the student’s  
22 performance on the summarizing activities. The summarizing exercises may include presentation  
23 of a sample summary and the opportunity for the student to submit a practice summary with  
24 immediate feedback derived from semantic space methods. The student may compose the

1 practice summary via one or more summary writing activities that provide step-by-step guidance  
2 through research-based strategies for summary writing. The summary writing activities may  
3 include writing a topic sentence, grouping related ideas, and writing topic sentences for the groups  
4 of related ideas. By using the actual lesson passage for practice, optimal conditions are achieved  
5 in the comprehension tutor for effective, efficient and engaging learning. Students greatly benefit  
6 from repeated reading of the lesson passage, and are able to work on improving their reading  
7 summarizing skills using material they need or want to learn, rather than predetermined and  
8 irrelevant “canned” material. The methods and measures for practice summaries are the same as  
9 those for non-practice summaries in that the practice summaries are evaluated using semantic  
10 space methods. The standards and criteria applied to practice summaries are the same as those  
11 for non-practice summaries.

12 The vocabulary tutor complements the main objective of improving the student’s  
13 comprehension of a lesson passage by focusing on principal vocabulary words in the passage, and  
14 serves in its own right to build and strengthen the student’s vocabulary as an independent criteria  
15 of literacy. The vocabulary tutor module 40, which comprises a body of software, automatically  
16 selects principal vocabulary words from the lesson passage for presentation to the student to  
17 review and learn. Principal vocabulary words, which may or may not be the same as the key  
18 words selected by the comprehension tutor module 38, are selected by the vocabulary tutor  
19 module 40 based on word features such as length, frequency of occurrence in printed matter,  
20 difficulty, as measured in many published indices, and/or for their novelty and utility with respect  
21 to the student’s sophistication as a reader. For the principal vocabulary words selected, the  
22 vocabulary tutor module 40 presents definitions, synonyms, antonyms, pronunciations, samples  
23 of correct usage and/or interactive practice exercises via computer system 10. Preferably, the  
24 vocabulary tutor module enables the principal words to be delivered audibly by the computer

1 system so that the student can hear the words spoken while viewing them to reinforce multi-  
2 modality learning. In the vocabulary tutor module 40, the production of definitions, synonyms,  
3 antonyms , and samples of usage for the principal vocabulary words can be automated in various  
4 ways, such as by incorporating the Word Net ® system into the vocabulary tutor module. Word  
5 Net ®, developed by the Cognitive Science Laboratory at Princeton University, is an on-line  
6 lexical reference system presenting English nouns, verbs, adjectives and adverbs organized into  
7 synonym sets, each representing one underlying lexical concept, with different relations linking  
8 the synonym sets. The practice exercises may include sample sentences using the principal  
9 vocabulary words correctly and incorrectly, with instructions for the student to click “correct” or  
10 “incorrect” on the monitor screen for each sentence. Additionally, the student may be instructed  
11 to “drag and drop” words appropriately into areas of the monitor screen labeled “synonyms” and  
12 “antonyms”. With the use of voice recognition system 25, the student may submit an audible  
13 reading of one or more principal vocabulary words for a determination whether the student is able  
14 to say the one or more words correctly. Information regarding the student’s performance on  
15 practice exercises is provided as feedback data 36.

16 The fluency tutor module 42 comprises a body of software permitting delivery of a lesson  
17 passage in audibly correct form through playback of a model recording, i.e. an author’s or  
18 instructor’s recitation of a lesson passage, or through a speech synthesis system. The fluency tutor  
19 module 42 evaluates a student’s recitation of the lesson passage and provides immediate  
20 feedback on the speed and accuracy of the student’s recitation. The fluency tutor module 42  
21 allows the student to hear an audibly correct reading or model recording of a lesson passage, to  
22 read the lesson passage aloud, and to have the student’s recitation of the lesson passage  
23 automatically evaluated for accuracy and speed against the audibly correct reading. The fluency  
24 tutor module may allow the student to listen to one’s own reading of the lesson passage. The

1 student's reading of the passage is timed and is translated to text by the voice recognition system  
2 25 for comparison to the original passage, which establishes a model of correct English  
3 expression. Immediate feedback on speed and accuracy is provided to the student as feedback  
4 data 36. Measures of speed and accuracy derived in the fluency tutor module 42 may be used by  
5 guidance algorithm modules in determining optimal guidance of the student through the domain  
6 of discourse.

7 The reading tutoring system 28 may include an authoring unit 44, which comprises a body  
8 of software operating in conjunction with the database and the command unit software and/or  
9 other software of the reading tutoring system to allow new instructional materials to be entered  
10 into the reading tutoring system and to allow existing instructional materials to be modified or  
11 deleted. With the authoring unit 44, instructors or system managers can enter new material with  
12 minimal authoring effort, such as by typing or scanning materials into the database for the reading  
13 tutoring system. Where the material to be entered is instructional text comprising one or more  
14 passages, the one or more semantic space modules, 34, 34' or 34" may be used to automatically  
15 rate the one or more passages for conceptual relatedness or similarity to existing passages in the  
16 domain, and may be used to assign the one or more passages in their proper location within the  
17 domain. Passages to be entered may be rated using other known measures of readability, and this  
18 may be accomplished automatically using separate software. Once the conceptual relatedness  
19 between passages to be entered and existing passages of the domain has been identified, the  
20 instructor or system manager can enter the passages in the domain at their proper locations,  
21 respectively.

22 In the reading tutoring systems and methods of the present invention, the one or more  
23 domains of discourse are analyzed and structured into a hierarchy of passages of different levels  
24 of reading difficulty as determined, for example, from passage length and readability or based on

1 the semantic complexity of their content. As shown in Fig. 3 for the domain of discourse 31, the  
2 passages within the domain are assessed for reading difficulty as represented by step 37 and are  
3 arranged or grouped according to their levels of reading difficulty and/or length as represented  
4 by step 39. Fig. 3 illustrates the passages assigned different levels of difficulty from Level One  
5 (least difficult) to Level Five (most difficult), with there being a plurality or group of different  
6 passages at each level. Fig. 3 illustrates passages 32A, 32B and 32C of Level One reading  
7 difficulty, passages 32D, 32E and 32F of Level Two reading difficulty, passages 32G, 32H and  
8 32I of Level Three reading difficulty, passages 32J, 32K, 32L and 32M of Level Four reading  
9 difficulty and passages 32N, 32O, 32P and 32Q of Level Five reading difficulty. Thus, when a  
10 student is directed by feedback data 36 to read a passage of Level Three difficulty, for instance,  
11 the feedback data 36 may direct the student to one of passages 32G, 32H or 32I, or may direct  
12 the student to select from passages 32G, 32H and 32I. Of course, the number of levels of  
13 difficulty and the number of passages at each level of difficulty can vary, with it being desirable  
14 to have many passages at each level. The number of passages at each level of difficulty can be the  
15 same or different. Fig.3 shows a greater number of passages at Level Four and Level Five  
16 difficulty due to the greater number of attempts which may be required for students to master  
17 these relatively more difficult levels of reading. Preferably, the passages cover a wide range of  
18 reading skill levels.

19 The passages are preferably related topically so that a student can progressively learn a  
20 student-specific topic or subject area while progressing through the domain of discourse.  
21 Accordingly, passages in Levels One through Five can be related and organized topically so that  
22 a student progressing through the domain of discourse learns the relevant subject area. Of course,  
23 one or more passages within a particular level of difficulty can be arranged and organized topically  
24 since a student may need to read more than one passage at a particular difficulty level.

1 Various methods can be used to assign difficulty ratings to the passages, including the use  
2 of human evaluators and/or readability formulas such as the Degree of Reading Power (DRP)  
3 system of Touchstone Applied Scientific Applications or the Lexile Framework of Metametrics,  
4 Inc. Difficulty levels may be established using factors such as vocabulary, syntax, text structure  
5 and ease of comprehension. The arrangement of passages making up the domain of discourse  
6 reflects the relationship among the passages across dimensions of readability and semantic  
7 relatedness. For example, from Levels One to Five, readability measures for the passages  
8 decrease from “high” (most easily readable) to “low” (least easily readable). A semantic  
9 relatedness measure (SRN) 41 is assigned between passages. Accordingly, the manner in which  
10 the passages of the domain are arranged reflects the progression of readability and the progression  
11 of semantic relatedness between the passages in a two dimensional framework.

12 A method of reading tutoring according to the present invention is illustrated in flow  
13 diagram in Fig. 4. The method of reading tutoring is conducted using computer system 10, by  
14 which the reading tutoring system 28 described above is accessed as represented by step 45. Upon  
15 accessing the reading tutoring system 28, a domain of discourse, such as domain of discourse 31,  
16 is selected for the student as represented by step 46. The domain of discourse may be pre-selected  
17 for the student by the reading tutoring system 28 or may be self-selected by the student from a  
18 plurality of domains of discourse, such as domains of discourse 31, 31' and 31", available in the  
19 reading tutoring system 28.

20 Once the domain of discourse has been selected for or by the student, the reading  
21 tutoring system 28 assigns the student a first passage from the domain of discourse to read and  
22 summarize as represented by step 48. The step of assigning the student a first or initial passage  
23 may involve selecting a passage from the next to lowest difficulty level, i.e. Level Two for the  
24 domain of discourse 31. The step of assigning the student an initial passage may include

1 consideration of data, if available, about the student's current reading level and/or skill. Initially  
2 assigning the student a passage of relatively low difficulty insures that the first passage is not too  
3 hard for the majority of students. The student can review the assigned passage and, if desired,  
4 self-select a passage that is harder or easier so that the student can self-assign the initial passage.  
5 Accordingly, a typical student should "pass" the initial level without much difficulty, thereby  
6 fostering the student's motivation and interest.

7 The student reads the first passage that has been assigned, which is displayed on monitor  
8 12, as represented by step 50. Thereafter, the student either uses the comprehension, vocabulary  
9 and/or fluency tutors offered by the reading tutoring system, as represented by steps 51, 52 and  
10 53, or submits a summary, typically 25-200 words long, of the first passage to the reading tutoring  
11 system as represented by step 54. As explained above, the summary will typically be submitted  
12 in writing, i.e. entered using keyboard 18, or orally, using the voice recognition system 25. The  
13 student-submitted summary is preprocessed in step 55, which includes utilizing the validity check  
14 module 33 to evaluate the summary for plagiarism and/or other anomalies. The step 55 may  
15 include preprocessing of the summary for various other purposes including conversion of the  
16 summary into a form more suitable for evaluation by the one or more machine learning modules.  
17 Preprocessing may be performed in various ways including lemmatization. The summary  
18 submitted by the student is automatically analyzed by one or more of the semantic space modules  
19 34, 34' and 34" of the reading tutoring system, as represented by step 56, to obtain a measure of  
20 the student's comprehension or understanding of the content of the first passage. Based on the  
21 evaluation performed by the one or more semantic space modules, feedback data 36 is provided  
22 to the student immediately as represented by step 57. The feedback data may be provided visually  
23 on monitor 18, audibly and/or in tangible written form via the printer 26. The feedback data, as  
24 described above, includes an indicator reflective of the student's comprehension of the content

of the first passage, as determined from the student-submitted summary using semantic space methods.

Where the student-submitted summary has demonstrated sufficient comprehension of the first passage, i.e. the summary and the passage contain appropriately similar concepts, the student may be considered as having “passed” the level of difficulty corresponding to the first passage as shown by step 58. In this case, the student is matched with an appropriate passage to read next, in accordance with the student’s current level of reading comprehension determined from the summary just analyzed, as represented by step 60. The level of difficulty of the passage to which the student is directed next may be determined in accordance with the similarity score and/or congruence assigned to the student-submitted summary. For example, where the first passage is of Level Two difficulty and the student’s summary achieves a relatively high similarity score, the reading tutoring system may match the student with an appropriate passage of Level Three difficulty or may instruct the student to select from a plurality of appropriate passages of Level Three difficulty in step 60. As another example, where the first passage is of Level Two difficulty and the student’s summary achieves a relatively low similarity score, the reading tutoring system may match the student with another passage of Level Two difficulty or may instruct the student to select from a plurality of other passages of Level Two difficulty and high semantic relatedness in step 60 to reinforce the student’s learning at the Level Two difficulty level. The one or more passages recommended by the reading tutoring system for the student to read next are provided as feedback data 36 to the student in step 60. The feedback data 36 provided in steps 57 and 60 may include various other metrics pertaining to the student’s performance as described above.

Where the student-submitted summary has demonstrated insufficient comprehension of the initially assigned passage, the student may be considered as “not passing” the level of difficulty of the initially assigned passage and is provided with feedback data 36 advising the

1 student to “try again” and/or to follow other designated instructions, as represented by step 62.  
2 In this case, the feedback data 36 presented in step 62 may offer or assign the student the  
3 comprehension tutor, the vocabulary tutor and/or the fluency tutor as represented by step 64. The  
4 feedback data 36 presented in step 62 may direct the student to read the initially assigned  
5 passage again as represented by step 66, or may match the student with another passage of  
6 appropriate difficulty, such as a passage of the same or lower difficulty than the initially assigned  
7 passage but with high semantic relatedness to the student-submitted summary, as represented by  
8 step 68. For a first passage of Level Two difficulty, for example, the reading tutoring system may  
9 instruct the student to utilize the comprehension tutor module 38 and, thereafter, to read the  
10 initially assigned passage again, may match the student with one or more other passages of  
11 Level Two difficulty, or may match the student with one or more passages of Level One  
12 difficulty, depending on the evaluation of the student’s previously submitted summary. After  
13 either of steps 60, 66 or 68, the process is repeated with step 50 wherein the student reads the  
14 newly assigned passage. At any time before or after submitting a summary, the student may use  
15 the comprehension tutor, the vocabulary tutor and/or the fluency tutor by repeating steps 51, 52  
16 and/or 53. If the student is redirected to the same passage in step 66, the student may be offered  
17 or assigned the comprehension tutor, the vocabulary tutor and/or the fluency tutor, or may  
18 independently access any or all of the tutors as represented by step 69.

19 A preferred manner of assigning the student a passage to read next uses the following  
20 method: where the student’s summary is “adequate”, the passage to read next is selected using  
21 semantic relatedness or similarity to the student’s summary; and, when the student’s summary is  
22 scored as “very good” or “very poor”, the passage to read next is randomly selected from the next  
23 higher or next lower level, respectively. Another method involves selecting a passage that has an  
24 appropriate overlap with the concepts contained in the student’s summary, without using

1 readability, where the only structure is the semantic relatedness of the passage.

2 Fig. 5 illustrates the additional steps in an alternative reading tutoring method according  
3 to the present invention wherein the student utilizes the comprehension or summary tutor module  
4 38, the features of which are also represented by Fig. 5. The comprehension tutor module 38 is  
5 accessed by the student via computer system 10 as represented by step 72. The comprehension  
6 tutor module 38 presents the student with a sample passage to read as represented by step 74, the  
7 sample passage typically being the instructional passage for which the student's reading  
8 comprehension is to be evaluated. The student reads the sample passage as represented by step  
9 75, and is presented with key words from the sample passage as represented by step 76 and/or  
10 is presented with interactive summarizing and instruction exercises as represented by step 78. The  
11 step 76 of presenting the student with key words may include presenting the student with  
12 highlighted terms in the sample passage, as indicated by step 80, which step may be self-selected  
13 by the student or may be executed automatically in that the highlighted terms can be embedded  
14 in the sample passage that the student reads. The step 78 of presenting the student with  
15 interactive instruction and summarizing exercises may be executed automatically by the  
16 comprehension tutor module or may be offered to the student as a self-selective option. The  
17 presentation of interactive summarizing instruction and exercises in step 78 may include  
18 presenting the student with instructional information, such as information on how to write a good  
19 summary, as represented by step 82, presenting the student with a concept identification activity  
20 as represented by step 84, presenting the student with a "cloze" activity as represented by step  
21 86, presenting the student with a sequencing activity as represented by step 88, and/or presenting  
22 the student with a summary writing activity as represented by step 90. The step 84 of presenting  
23 the student with a concept identification activity includes presenting the student with instructions  
24 for identifying core concepts of the lesson passage and its related ideas. The step 86 of presenting

1 the student with a “cloze” activity includes presenting the student with a version of the lesson  
2 passage that has a plurality of blank spaces where words are missing and instructions for the  
3 student to “drag” or type appropriate words on the monitor screen into the blank spaces to  
4 complete the lesson passage correctly. The step 88 of presenting the student with a sequencing  
5 activity includes presenting the student with randomly arranged sentences from the lesson passage  
6 and instructions for the student to arrange the sentences into their correct order. The step 90 of  
7 presenting the student with a summary writing activity may include presenting the student with  
8 strategies for summary writing and/or instructions for the student to compose a topic sentence,  
9 to group related ideas and/or to compose topic sentences for the groups of related ideas, and/or  
10 may include instructions for the student to submit a practice summary to the reading tutoring  
11 system, as represented by step 92. Once the practice summary has been accepted by the reading  
12 tutoring system in step 92, the practice summary is evaluated by the reading tutoring system in  
13 step 94 in the same manner as a non-practice summary as discussed above. Immediate feedback  
14 data 36 regarding the student’s performance on the exercises or activities of the comprehension  
15 tutor is provided to the student as represented by step 96. Where the student submits a practice  
16 summary of the sample passage to the reading tutoring system, step 96 includes providing the  
17 student information on the quality of the practice summary as discussed above for non-practice  
18 summaries.

19 Another alternative reading tutoring method according to the present invention wherein  
20 the vocabulary tutor is utilized is illustrated in Fig. 6, which is also representative of the features  
21 of the vocabulary tutor. The vocabulary tutor module 40 is accessed by the student via the  
22 computer system 10 as represented by step 100. As represented by step 101, the vocabulary tutor  
23 module automatically selects principal vocabulary words for the lesson passage read by the  
24 student in step 50 described above, the principal vocabulary words being selected based on word

1 features such as length, frequency of occurrence in printed matter, and/or difficulty as measured  
2 in a variety of published indices. The student is presented with the principal vocabulary words  
3 as represented by step 102, which may include presenting the student with definitions for the  
4 principal vocabulary words as represented by step 104, presenting the student with synonyms for  
5 the principal vocabulary words as represented by step 106, presenting the student with antonyms  
6 for the principal vocabulary words as represented by step 108, presenting the student with samples  
7 of correct usage for the principal vocabulary words as represented by step 110 and/or presenting  
8 the student with pronunciations for the principal vocabulary words as represented by step 112.  
9 Any of the steps 104-112 may be presented to the student automatically or may be self-selected.  
10 Any of steps 104, 106, 108, 110 or 112 may include the step 114 of presenting the student with  
11 interactive practice exercises. Step 114 may include, for example, the step of presenting the  
12 student with sentences using a principal vocabulary word correctly and incorrectly and  
13 instructions for the student to “click” “correct” and “incorrect” on the monitor screen for each  
14 sentence. Step 114 may include the step of presenting the student with a plurality of words and  
15 instructions for the student to “drag and drop” the words into areas of the monitor screen labeled  
16 “synonyms” and “antonyms”. Step 114 may include instructing the student to submit an audible  
17 reading of one or more principal vocabulary words, as implemented via the voice recognition  
18 system 25, for a determination whether the student is able to pronounce the one or more words  
19 correctly. Immediate feedback for the interactive practice exercises is provided to the student  
20 as feedback data 36, as represented in step 116. In the preceding examples, the step 116 may  
21 include presenting the student with the correct usages for the sentences, with the correct  
22 designations for the words, and with indications of whether the student’s pronunciations of the  
23 words are correct, with or without accompanying explanations. The step 112 of presenting the  
24 student with pronunciations may include presenting the student with audible pronunciations of

principal vocabulary words so that the student may listen to the correct pronunciation for a word before and/or after submitting an audible reading of the word.

Fig. 7 illustrates a further alternative method of reading tutoring according to the present invention utilizing the fluency tutor, the features of which are represented in Fig. 7. The fluency tutor module 42 is accessed by the student via computer system 10 as represented by step 118. The student is presented with a sample passage to read aloud, as represented by step 120. Typically, the sample passage is the instructional passage for which the student's reading comprehension is being evaluated, i.e. the passage assigned to the student in step 48. In response to a request entered by the student, an audibly correct reading of the sample passage is played aloud as shown by step 122. After listening to the audibly correct reading, the student may practice reading the sample passage aloud to improve fluency. When the student is ready, the student dictates or submits an audible reading of the sample passage via computer system 10, represented by step 124. The student's audible reading is converted to text in step 125, as made possible by the voice recognition system 25. The student's audible reading of the sample passage is evaluated automatically for accuracy, as indicated by step 126, and speed, as represented by step 128. Based on the evaluation performed in steps 126 and 128, immediate feedback data 36 on the accuracy and speed of the student's audible submission is provided to the student in step 130.

With the reading tutoring systems and methods of the present invention, a student begins learning at an appropriate difficulty level and is thereafter guided to the most appropriate difficulty level for the student in a path of optimal learnability. Different modalities are utilized in the reading tutoring system and methods, thereby accommodating individual learning differences of students. Student summaries can be submitted in written (typed) or audible forms such that reading comprehension skill is not confounded with writing skill. A student's prior and

1 developing knowledge is used to match the student to the most appropriate instructional  
2 passages. The instructional passages are arranged in a “curriculum” that is matched to an  
3 individual student in a manner that maintains motivation and optimizes learning. The task of  
4 improving reading comprehension is embedded within instructional material that contains  
5 knowledge the student wants or needs to acquire. The process of constructing large corpora of  
6 instructional text spanning a wide range of reading skill levels is facilitated and made more  
7 accurate. The validity and reliability of measures taken to construct instructional passages is  
8 promoted. The instructional text may contain a broad variety of content areas appealing to diverse  
9 students. Word recognition and lower-level lexical processing during reading are facilitated.  
10 Speech recognition technology integrates oral input with the assessment and instructional  
11 methods. The graphical user interface integrates assessment with instruction so that students with  
12 a history of unsuccessful reading and testing will feel more comfortable and less intimidated.  
13 Motivation to learn is enhanced, thereby improving the rate and extent of a student’s acquisition  
14 of reading comprehension skills and knowledge of the subject matter. The special characteristics  
15 of adult learners are accounted for and capitalized on. Immediate feedback is provided to the  
16 student on how well the student is understanding the instructional material. A student is able to  
17 access automated tutors for more focused and specialized skill development in the areas of  
18 comprehension, vocabulary and/or fluency. A student is automatically guided to the next  
19 instructional passage that is most likely to improve the student’s comprehension. Validity checks  
20 can be incorporated to “flag” suspect summaries. Student-submitted summaries may be  
21 preprocessed in various ways, including lemmatization, for various purposes, including validity  
22 and/or conversion of the summaries into a more desirable form for evaluation by the semantic  
23 space module. The comprehension, vocabulary and fluency tutors enhance the acquisition of  
24 reading and interrelated skills in an automated, interactive environment. The tutors provide a

1 more complete understanding of a student's current reading competence and any special needs.  
2 Students, particularly adults, can learn and practice difficult skills in a private environment.  
3 Reading comprehension can be improved for students in various applications including military,  
4 civilian, academic and non-academic applications. The reading tutoring systems and methods can  
5 be used anytime and anywhere there is access to a computer or Internet connection.

6 The reading tutoring systems and methods could include graphical maps for various  
7 purposes, such as representing story structure to reinforce its effect on reading comprehension.  
8 The authoring unit may be designed to provide authoring support for the comprehension,  
9 vocabulary and fluency tutors. The authoring unit may provide textual entry and editing support  
10 for the tutor modules allowing the instructor or system manager to add, modify, or delete items  
11 or text from the tutor modules and/or the feedback data therefor. The authoring unit may also  
12 support audio recording and playback to allow the instructor or system manager to record and  
13 save audio input. The authoring unit may additionally support and implement speech recognition  
14 training whereby the student can "train" the voice recognition system to the student's own speech  
15 and voice. The authoring unit may allow such "training" to be accomplished using reading  
16 material automatically selected for a particular student in accordance with the student's current  
17 reading level. The authoring unit may be designed to automatically enter new instructional  
18 passages at their proper locations in the domain. The authoring unit may utilize semantic space  
19 methods, such as semantic space algorithms, to evaluate instructional passages to be entered, such  
20 as in relation to those already entered, in order to determine the proper locations for the  
21 instructional passages to be entered. It should be appreciated from the foregoing that the  
22 authoring unit can be designed in various ways to facilitate customization of the reading tutoring  
23 system, including customization of the individual tutors, with minimal human effort and  
24 intervention. Semantic space methods, such as semantic space algorithms, may be utilized to  
25 construct the domain of discourse in that a number of passages may first be rated for difficulty by

human evaluators, the Lexile framework or another rating system, and then measures of semantic similarity between the rated passages and all remaining passages in the domain may be used to rate the remaining passages for semantic relatedness. The one or more semantic space modules of the reading tutoring system can be used to automatically assess the difficulty of the passages of the domain and to automatically arrange or group the passages according to their assessed levels of difficulty. Use of the comprehension tutor may include presenting the student with multiple-choice tasks of locating the main ideas, key concepts and important and unimportant details from the sample passage. Student-submitted summaries may be evaluated in various ways by using semantic space methods including comparison of student-submitted summaries to the original lesson passages, to model summaries and/or to random summaries.

Although the command unit, the semantic space module, the authoring unit, the validity check, the comprehension tutor, the vocabulary tutor and the fluency tutor have been shown as separate “units” or “modules”, it should be appreciated that the software for each may be part of a single body of operating software. All or portions of the software for executing the functions of the tutor modules, the command unit, the semantic space module, the authoring unit, the validity check module, and/or other functions or features of the reading tutoring systems and methods may be part of the operating software and may be integrated with or distinct from one another.

Having described preferred embodiments of reading tutoring systems and methods, it is believed that other modifications, variations and changes will be suggested to those skilled in the art in view of the teachings set forth herein. It is therefore to be understood that all variations, modifications and changes are believed to fall within the scope of the present invention as defined by the pending claims.